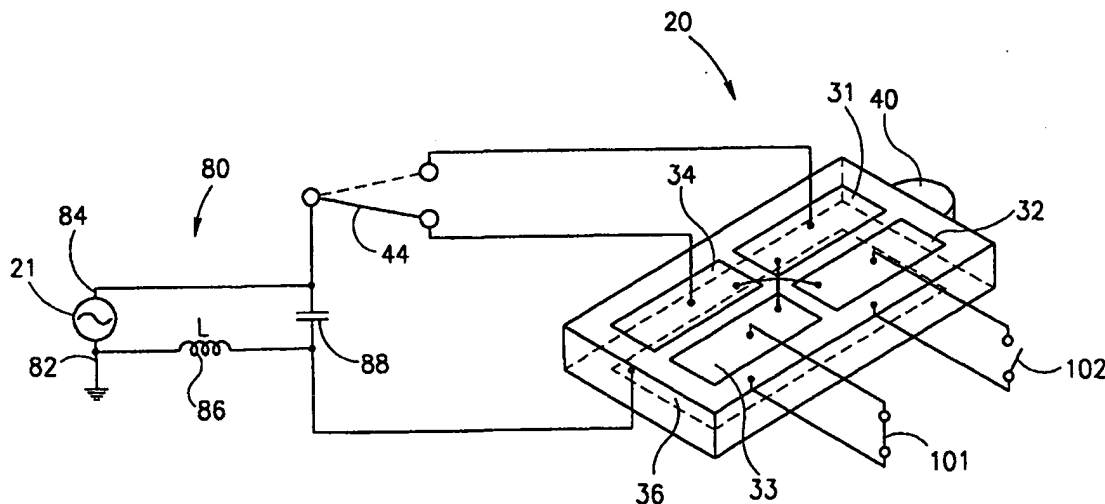


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(54) Title: METHOD AND APPARATUS FOR DRIVING PIEZOELECTRIC MOTORS

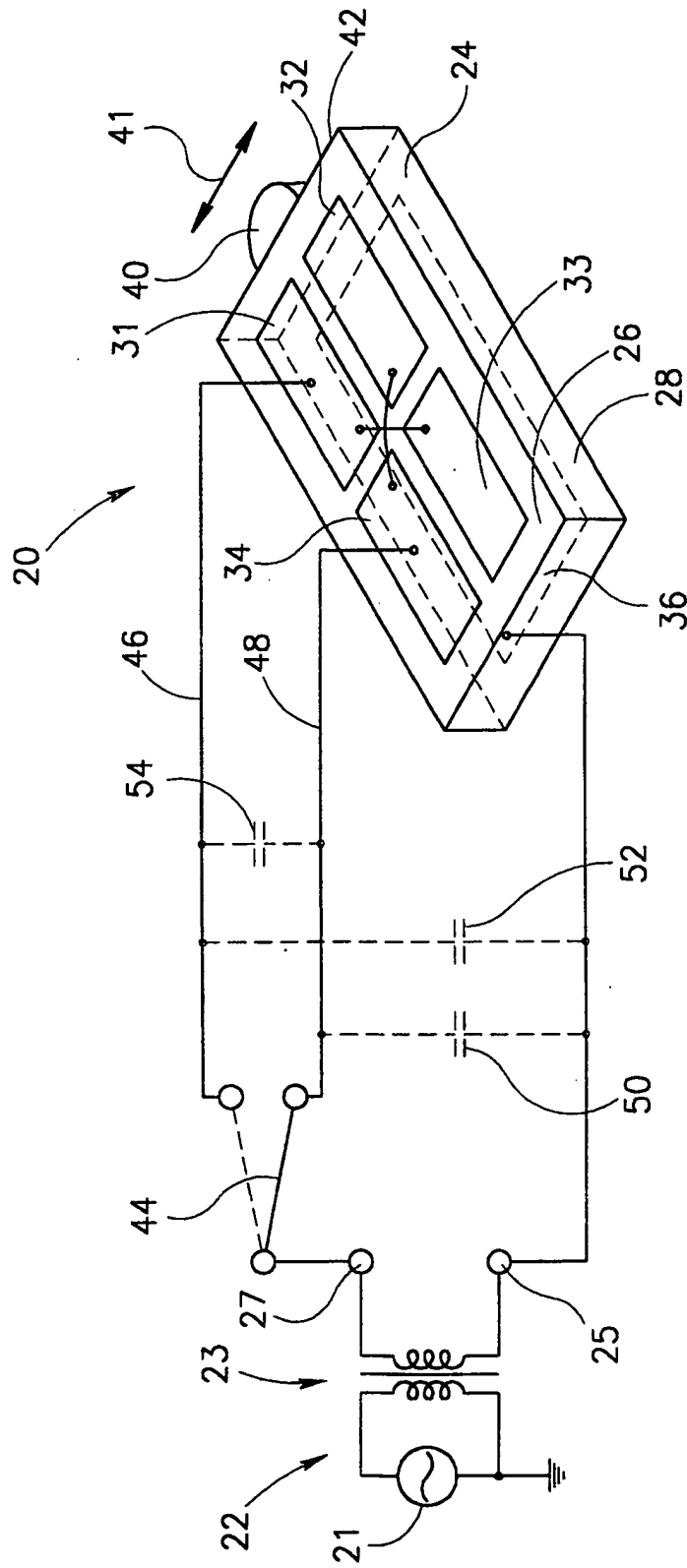


(57) Abstract

A method is provided for exciting vibrations in a piezoelectric motor having a plurality of electrode sets, each set comprising at least one first electrode and at least one second electrode between which AC voltages are applied to excite vibrations in the piezoelectric motor, the method comprising: coupling an AC power source to the at least one first electrode and at least one second electrode of a first electrode set; electrically connecting the at least one first electrode to the at least one second electrode of a second set of electrodes with a non-zero impedance that is substantially less than an impedance between them resulting from stray capacitive coupling; and energizing the power source to apply an AC voltage difference between the at least one first electrode and at least one second electrode of the first set of electrodes to excite the vibrations.

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FIG. 1A
PRIOR ART



METHOD AND APPARATUS FOR DRIVING PIEZOELECTRIC MOTORS**FIELD OF THE INVENTION**

The invention relates to piezoelectric motors and in particular to methods for powering piezoelectric motors using resonant circuits.

BACKGROUND OF THE INVENTION

Generally, a piezoelectric micromotor is driven with a high voltage AC driving circuit that applies an alternating polarity voltage difference between at least one first electrode and at least one second electrode comprised in the piezoelectric micromotor. The frequency of the AC voltage difference applied to the electrodes is close to a desired frequency of vibration of the piezoelectric motor. To assure proper operation of the motor, the power supply is electrically matched to electrical characteristics of the motor so that power is efficiently transmitted to the motor at the desired frequency of vibration. The at least one first electrode, hereinafter referred to as a first "driving electrode", and at least one second electrode, hereinafter referred to as a second "driving electrode", define a "driving set" of electrodes of the piezoelectric motor.

Often a piezoelectric motor comprises more than one driving set of first and second driving electrodes. Different driving sets of first and second driving electrodes are electrified to excite different desired vibration modes in the piezoelectric motor. Electrodes that are electrified by direct connection to a driving circuit while exciting a desired vibration mode are said to be active electrodes and a driving set to which the electrodes belong is said to be an active driving set. Electrodes that are not electrified by direct connection to the driving circuit while exciting a particular vibration mode and the driving sets to which they belong are said to be passive. Passive electrodes are either floating or grounded.

Transmission of power to a desired vibration mode of the piezoelectric motor is generally sensitive to changes in stray capacitance between passive electrodes and ground and changes in capacitance between conducting wires, hereinafter referred to as "driving lines" that connect the driving circuit to the piezoelectric motor. Hereinafter, stray capacitance to ground and capacitance between driving lines are referred to generically as stray capacitance. Changes in stray capacitance generate mismatches between desired resonant vibration frequencies of the motor and frequencies at which power is efficiently transmitted from the driving circuit to the motor. These mismatches can substantially degrade the performance of the piezoelectric motor.

In particular changes in stray capacitance are caused by changes in the lengths the driving lines used to connect the driving circuit to the motor. For example, assume that the driving circuit is matched to a resonant frequency of the piezoelectric motor and that the

CLAIMS

1. A method for exciting vibrations in a piezoelectric motor having a plurality of electrode sets, each set comprising at least one first electrode and at least one second electrode between which AC voltages are applied to excite vibrations in the piezoelectric motor, the method comprising;
- 5 coupling an AC driving circuit to the at least one first electrode and at least one second electrode of a first electrode set;
- electrically connecting the at least one first electrode to the at least one second electrode of a second set of electrodes with a non-zero impedance that is substantially less than an impedance between them resulting from stray capacitive coupling; and
- 10 energizing the driving circuit to apply an AC voltage difference between the at least one first electrode and at least one second electrode of the first set of electrodes to excite the vibrations.
- 15 2. A method according to claim 1 wherein electrically connecting the at least one first electrode to the at least one second electrode of the second set of electrodes comprises connecting them with a first capacitor having a capacitance substantially larger than a capacitance between them resulting from stray capacitive coupling.
- 20 3. A method according to claim 2 wherein connecting a first capacitor comprises closing a switch, which switch is operable to be open or closed to respectively disconnect the first capacitor from the electrodes and connect the first capacitor to the electrodes.
4. A method according to claim 3 wherein coupling an AC driving circuit to the at least one first electrode and at least one second electrode of the first electrode set comprises opening
- 25 a switch, which switch is operable to be open or closed to respectively disconnect a second capacitor from between the electrodes and connect the second capacitor between the electrodes.
5. A method according to claim 2 and comprising connecting the at least one first
- 30 electrode to the at least one second electrode of the first electrode set with a second capacitor having a capacitance substantially larger than a capacitance between them resulting from stray capacitive coupling.

INTERNATIONAL SEARCH REPORT

Int. onal Application No
PCT/IL 99/00520

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L41/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 712 170 A (NANOMOTION LTD) 15 May 1996 (1996-05-15) figure 7 -----	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
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1 February 2000

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